Fermilab
Accelerator Division
Linac Department

"LANA"

A Computer Code for Beam Dynamics Simulation in Multi-Cavity Linacs and its Application to the Fermilab Linac Upgrade

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I. Introduction:

The LANA computer code has been developed by D.V. Gorelov and P.N. Ostroumov of the Institute for Nuclear Research (INR) of the Russian Academy of Sciences, Moscow. Its primary purpose is for 3-dimensional beam dynamics simulation in DTL, DAW, SCS and similar linac accelerating structures. The code was originally developed in order to simulate commissioning procedures at the Moscow Meson Factory (MMF) linac primarily the delta-T procedure for setting rf amplitude and phase. Other applications have included the simulation of beam transport and determination of transverse lattice parameters in the MMF linac. The code was originally developed in the FORTRAN programming language for IBM-PC compatible (386/486) computers and has been adapted to run under the UNIX operating system of a Sun workstation with a user input interface and graphics output interface utilizing the X-Windows system.

II. Model:

The LANA code uses a 3-dimensional multiparticle Monte-Carlo model with no space charge effects. A "square" wave approximation of the accelerating field and of the magnetic field in quadrupoles is used. Current work on the code consists of an improved determination of the structure of the accelerating field. A linear matrix transformation is used for simulation of the linac structure except for the calculation of longitudinal motion in the accelerating gap.

Simulation is provided for a number of independent sequential linac cavities. Every accelerating cavity can consist of one or more sections where the rf-field amplitude and phase are the same. Upstream of the cavity and downstream of every section a focussing system can be simulated. This focussing system consists of quadrupole magnets and drift spaces. Every section is simulated as a number of accelerating cells each cell having a unique length of first half drift tube, accelerating gap, and second half drift tube. For every cell there is a corresponding input and output beta, and every tube and half-tube of a section has a corresponding quadrupole length and gradient (for DTL). The matrices used for the dynamics simulation are described in [1-3] for transverse motion and in [4,5] for longitudinal. The accelerating gap is calculated in transverse planes as thin lenses on the edges and drift space in the gap taking into account relativistic effects. Different linac structures are described by the periodicity of their acceleration (K) - the length of the accelerating cell in terms of beta*lambda. For DTL K=1, for DAW or SCS K=1/2.

The initial distribution of particles is created to fit the user specified transverse and longitudinal Twiss parameters using the Monte-Carlo method. The particle distribution in the longitudinal phase space can be created with either a parallelogram or an elliptical uniform distribution. In the transverse planes, either a 4-dimensional phase space elliptical uniform distribution or an elliptical uniform distribution can be created for the X and Y planes independently. It is also possible to use two thin buncher gaps upstream of the linac to create the proper initial longitudinal distribution at the entrance of the linac.

The code also provides results for use in calculations involved in the delta-T procedure of setting rf amplitude and phase. These results correspond to the notation used in [6].

III. Algorithms:

To describe particle motion properly in the square wave approximation some algorithms for choosing the design rf-field parameters are used.

For a DTL linac the proper rf-field amplitude is chosen for a synchronous particle which has the appropriate beta after every cell. The phase advance of the synchronous particle is corrected at the exit of every cell to the proper value of 2 pi. This correction is connected to the difference between the model used in this code and the model used for design geometry generation. This correction value is typically less than 1 degree and is used for all particles in the corresponding cell.

For a DAW or SCS linac, with -pi/2 synchronous phase (relative to the field maximum in the gap), the proper rf-field amplitude is chosen for a reference particle which has the same phase upon entering and exiting the module. The reference particle is defined here as the particle which has designed acceleration in the section. In this algorithm the phase of the reference particle is not the same at the input and output of the individual sections but is fulfilled for the whole cavity. Actually the input and output phases for a section differ by about 1-4 degrees for different cavities (for the Fermilab Linac Upgrade this value is less than 1 degree). The input phase of the reference particle can be a constant as defined in the input data file or as a variable phase that corresponds to a defined average phase along whole cavity. The phase advance of the synchronous particle is corrected to pi for each cell (in a similar manner as the correction for the DTL structure).

IV. Input Information:

User supplied input informations consists of:

1) initial particle distribution shape and Twiss parameters.

2) parameters for up to 2 bunchers.

3) cavity parameters:

   i) channel aperture.

   ii) rf wavelength.

iii) structure of cavity, e.g. number of cells, drift tube lengths, accelerating gap lengths, quadrupole gradient and lengths (DTL).

iv) particle beta at end of each accelerating cell.

v) input phase of synchronous/design particle.

vi) focussing system, e.g. location of quadrupoles, gradients.

Available options include:

1) specification of initial and final cavity number to be simulated.

2) simulation of rf instability errors in the rf phase and amplitude.

3) scanning of rf phase for one cavity.

4) longitudinal and transverse acceptance calculations beginning at an arbitrary cavity.

5) run-time display of Twiss parameters, maximal and rms envelopes along the cavity, and average beam energy.

6) full 6-dimensional phase space particle dynamics in graphical form.

7) simulation of bending magnet system.

V. Applications for Fermilab Linac Upgrade:

The following are calculations that have been (or will be) completed prior to the commissioning of the Fermilab Linac Upgrade. It is anticipated that these calculations will help in the understanding of data obtained during the commissioning procedure.

1) Determination of Beam Energy upon output from each cavity as a function of the rf amplitude and phase.

2) Calculation of longitudinal and transverse acceptance at monitoring positions (wire scanners) along the linac.

3) Optimization of rf amplitude and phase in DTL tanks to match to SCS of the Linac Upgrade.

4) Simulation of the use of spectrometer magnet as an energy filter to determine coarse settings of the rf phase and amplitude.

5) Calculation of Delta-T parameters.

6) Determination of transverse lattice parameters for transport of unaccelerated beam through linac.

VI. References:

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